

2.1.10. TALL TOWERS PROGRAM

There are 2 full years of continuous CO₂ data from the 610-m tall TV tower in eastern North Carolina (35°21'55"N, 77°23'38"W, 9 m above sea level). For measurements at 496 m above the ground, the rate of data return is about 85%. There are also measurements at 51 and 123 m. Some statistics of the data for June 1993 through May 1994 are given in Table 2.6 (data for June 1992 through May 1993 are given in *Peterson and Rosson* [1993]). In addition, flask samples for CO, CH₄, and isotope (¹³C/¹²C and ¹⁸O/¹⁶O in CO₂) analysis are collected from the 496-m level once each week.

In Figure 2.19 the daily afternoon (1500-1700 LST) mean CO₂ mixing ratios at 496-m height on the North Carolina tower are plotted with the flask data from the two Bermuda sites (BME and BMW). The difference between the mixing ratios at these locations gives an approximate measure of the afternoon drawdown or increase in CO₂ within the atmospheric boundary layer at the tower site because of

regional surface fluxes. In winter, the afternoon means at 496 m on the tower are generally 2-5 ppm higher than at Bermuda, likely reflecting small net respiration and CO₂ emissions from fossil fuel combustion around the tower site. In summer, afternoon means at the tower are typically 2-10 ppm lower than at Bermuda, indicating rapid daytime photosynthesis in the vicinity of the tower. Occasionally (i.e., a few times per summer), unusually low CO₂ mixing ratios are observed in the flask samples from Bermuda. For example, air samples taken at BME and BMW on September 3 and 4, 1992, respectively (plotted as triangles in Figure 2.19), show values 5-10 ppm below those obtained for the previous and subsequent weeks. These low values fall within the range of afternoon mixing ratios observed during the same period at the tower, suggesting that the samples may reflect transport of low-CO₂ air from the continental boundary layer to Bermuda. Isobaric back trajectory analysis (J. Harris, personal communication, 1993) shows rapid (1-2 day) transport of air from the southeast United States to Bermuda during this period.

TABLE 2.6. Statistics of Daily Mean and Median CO₂ Mixing Ratios at the 51-, 123-, and 496-m levels on the North Carolina Tower

	51 m		123 m		496 m					
Month	Mean	Median	Mean	Median	Mean	STDV	Median	LQ	UQ	N*
1993										
June	NA	NA	361.87	361.67	355.35	2.84	355.48	353.46	357.82	22
July	370.11	369.16	361.52	361.47	353.80	3.80	353.85	351.10	356.46	31
Aug.	364.45	364.35	355.90	354.98	350.76	4.38	351.80	347.24	354.56	26
Sept.	370.20	366.24	363.07	361.92	355.83	4.45	354.88	353.50	358.46	29
Oct.	365.79	363.09	362.15	360.94	356.96	4.83	355.81	353.74	359.00	11
Nov.	368.83	368.52	366.59	364.81	362.22	3.78	362.29	359.20	364.59	27
Dec.	369.59	369.73	368.00	367.99	364.83	2.77	364.99	362.43	367.18	29
1994										
Jan.	369.89	369.68	368.94	368.12	365.99	3.23	365.49	364.42	367.19	20
Feb.	370.80	369.46	369.07	367.27	366.23	4.32	364.89	363.21	367.43	28
March	368.80	369.83	367.17	366.90	365.15	2.15	364.77	363.77	366.14	25
April	369.71	368.83	367.05	366.51	363.42	2.49	363.74	361.67	364.99	29
May	366.28	366.35	363.49	363.38	360.63	2.94	360.99	359.47	362.02	26

LQ and UQ indicate lower and upper quartiles, respectively.

NA indicates data not available.

*Number of days used in the average.

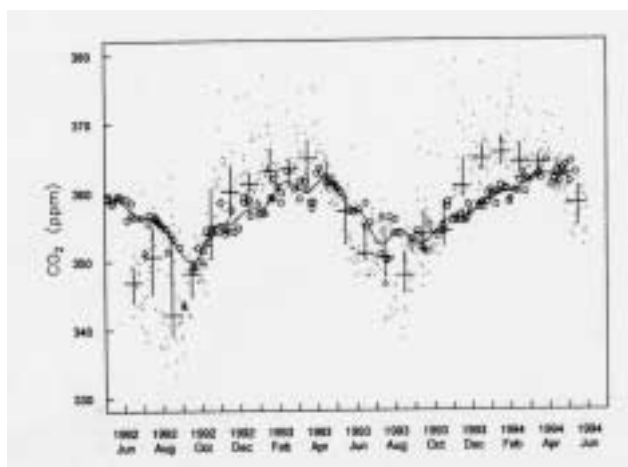


Fig. 2.19. Daily afternoon (1500-1700 LST) CO_2 mixing ratios at 496 m on the North Carolina tower (points) and CMDL flask data from Bermuda (open symbols). The large crosses denote monthly medians (horizontal bars) and inner quartiles (vertical bars) of the tower data, and the solid line is a smoothed fit [Thoning *et al.*, 1989] to the Bermuda data (circles), with points lying more than two standard deviations from the curve plotted as triangles.

The isotopic composition of CO_2 carbon in flask samples collected at 496-m height is shown in Figure 2.20, plotted against the reciprocal of CO_2 mixing ratio. In this plot the intercept ($1/\text{CO}_2 = 0$) gives a measure of the isotopic composition of the CO_2 source or sink that causes the observed variations in CO_2 mixing ratio. Cold and warm season data show significantly different relationships. During the cold season the CO_2 source has an isotopic composition of $-28.2 (\pm 1.0, 1 \text{ standard deviation})\text{‰}$, close to the value for the global average fossil fuel source of -28.5‰ [Andres *et al.*, 1995]. This result indicates that regional sources are dominated by fossil fuel combustion during the colder half of the year. In the warm season a much heavier ($-22.8 (\pm 1.0)\text{‰}$) CO_2 flux signature is indicated by the isotope measurements, consistent with the increased contribution of biological processes.

The relationship between CO and CO_2 in flask samples taken weekly from the 496-m level are shown in Figure 2.21. Carbon monoxide is a product of incomplete combustion of organic material (fossil fuel and biomass) and is also formed in the atmosphere from the photooxidation of CH_4 and other hydrocarbons. Carbon monoxide is removed from the troposphere mainly by reaction with the hydroxyl radical, and the lifetime of CO in the troposphere at the latitude of the tower ranges from around 1 month in summer (when OH is most abundant) to greater than 12 months in winter [Novelli *et al.*, 1992]. A strong linear relationship exists between CO and CO_2 at

the tower in winter (November-March, slope = $12.7 (\pm 0.8)$ ppb CO/ppm CO_2 , $r^2 = 0.93$, with three outliers removed based on examination of the residuals). The photochemical sources and sinks of CO, and the biogenic sources and sinks of CO_2 , are slow in winter and the relationship in Figure 2.21 likely reflects a combustion source for both species. The slope of the relationship is about 60% of that expected from CO and CO_2 emission inventories for fossil fuel combustion in the United States [J. Logan, personal communication, 1993; Bakwin *et al.*, 1994], probably because the source of CO_2 from soil respiration is not zero in winter. In summer, biogenic sources and sinks of CO_2 dominate fossil fuel sources, and no discernible relationship between CO and CO_2 was found.

A significant linear relationship was observed between CO and CH_4 in all seasons (Figure 2.22). The slope for wintertime data only is indistinguishable from the slope for all of the data, but the correlation is somewhat better in winter ($r^2 = 0.81$ for winter, $r^2 = 0.54$ for all data). This result probably reflects colocated industrial sources for CO and CH_4 (e.g., population centers). Apparently, regional biogenic sources and sinks for CH_4 are small relative to urban-industrial sources.

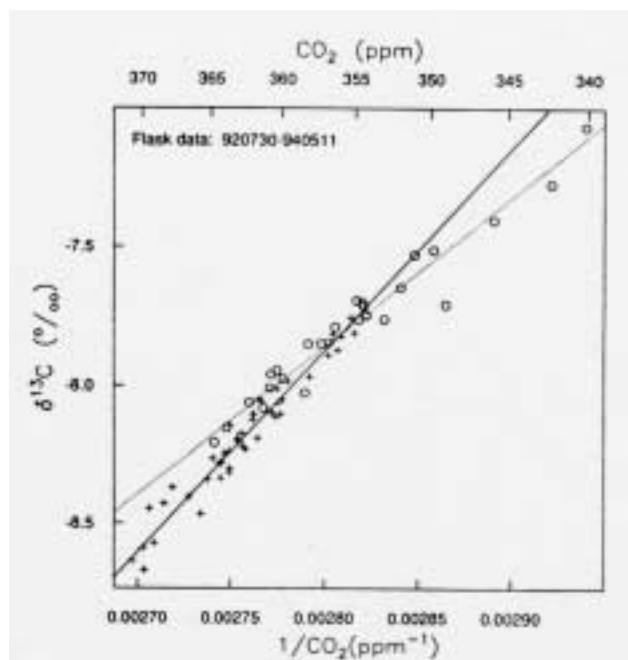


Fig. 2.20. The relationship between $\delta^{13}\text{C}$ and CO_2 in flask samples from 496 m on the North Carolina tower. Cold season (November-April, pluses and solid line) and warm season (May-October, circles and dashed line) data are plotted separately. The intercepts of orthogonal distance regression [Press *et al.*, 1992] lines are $-28.2 \pm 1.0\text{‰}$ ($r^2 = 0.95$, $n = 43$) for the cold season, and $-22.8 \pm 1.0\text{‰}$ ($r^2 = 0.95$, $n = 27$) for the warm season.

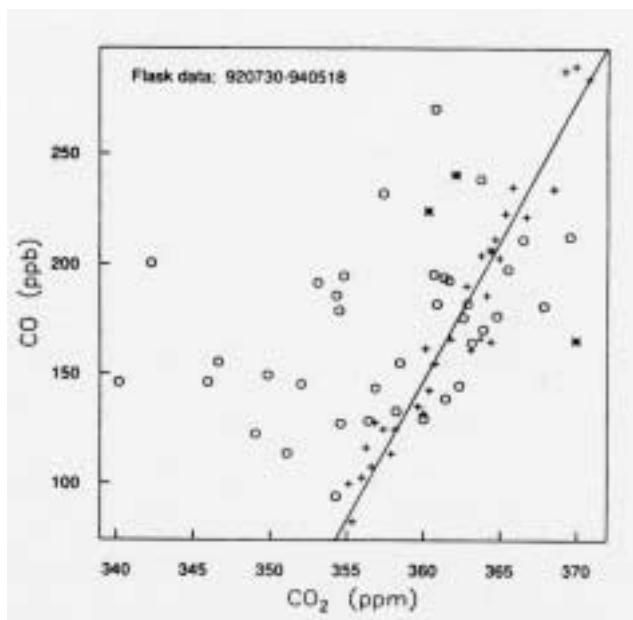


Fig. 2.21. The relationship between CO and CO₂ in flask samples taken weekly from the 496 m level on the North Carolina tower. Winter (November-February, pluses) and non-winter (circles) data are plotted separately, and the slope of an orthogonal distance regression to the wintertime data only (with three outliers (stars) excluded on the basis of examination of the residuals) is 12.7 ± 0.8 ppb/ppm ($r^2 = 0.93$, $n = 32$).

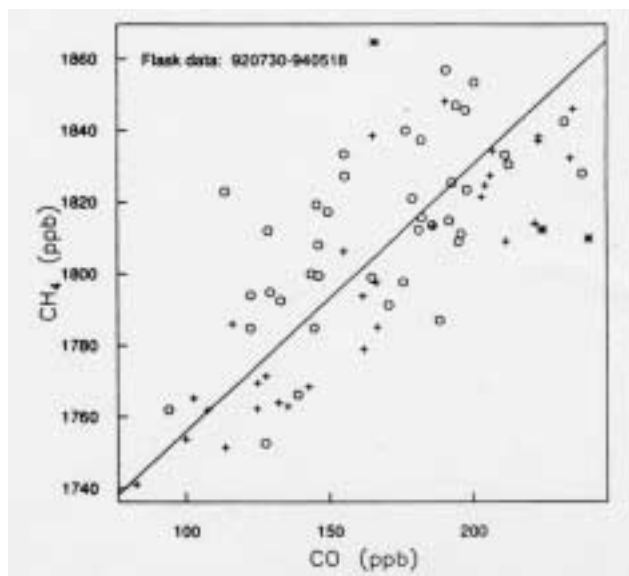


Fig. 2.22. The relationship between CH₄ and CO₂ in flask samples from 496 m above the surface. Winter (November-February, pluses) and non-winter (circles) data are plotted separately. The orthogonal distance regression line is fit to all of the data, and the slope is 0.70 ppb/ppb ($r^2 = 0.66$, $n = 144$). Three data points (stars) were excluded from the wintertime data analysis on the basis of the CO versus CO₂ relationship (see Figure 2.21).